

# Black-Scholes and Monte-Carlo Simulation: Design of a Web-Based Stock Option Pricing Accuracy Comparison Application

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**Abstract:** Options are legal contracts that give the right to buy/sell the underlying instrument at a specific price and time. For most types of Options, traditional calculation techniques are very difficult to use due to the complexity of the instruments. For this reason, the research intends to create a calculation system that can determine the price of European Type Stock Options using the Monte Carlo and Black-Scholes simulation methods. In this research, an object-oriented application called SOCA was developed using the prototype method, made website-based using the Python programming language. Based on the evaluation results of the user interface using 8 golden rules and 5 measurable human factors, it is known that the available information and features are in accordance with user needs, the application is also easy to use. The results of the evaluation using the black box show that all functional systems can run well. From the results of the evaluation and testing carried out, it can be concluded that the application has been made according to the needs of its users.

**Keywords:** Black-Scholes, Monte Carlo, Stock Options, SOCA, Simulation, Python, Prototype

## 1. Introduction

Over time, Indonesia's economic growth is growing rapidly. One of the factors that can influence Indonesia's economic growth is investment. According to [1], investment means placing funds or committing funds with the aim of obtaining results from these funds for a certain period, which is usually in the form of periodic cash flows and or final value. According to [2] the sensitive condition of interest rate changes, the banking world, especially in managing the sources and use of funds, really needs a system that can function and play a role in monitoring and controlling fluctuating interest rate movements. Gap Management is an effort to manage and control the gap (Gap) between assets and liabilities in the same period, including gaps in terms of the amount of funds, interest rates, maturity or a combination of the three. Decisions in Gap management include changing the term structure of the liability in determining the source of funds and the interest rate, changing the term structure of assets in changing credit policies and in terms of selling investments.

Several companies currently offer several attractive business options to reduce possible risks when investing. The main option is Options. An option is a formal contract that gives the right (but not the obligation) to buy or sell a specified number of the underlying instrument at a specified price and within a specified time period. There

are two types of options known, namely call options and put options. A call option is an option that gives the holder the right (not the obligation) to purchase a specified amount of an instrument on which the contract is based for a specified amount at a specified time and price. A put option is an option that gives the holder the right (not the obligation) to sell a specified number of instruments on which the contract is based for a specified amount at a specified time and price [3]. The function of Options is to reduce risk as well as increase profits with greater leverage. There are 3 types of options, namely European Options, American Options and Asian Options. This classification is determined based on the period of time usage [4].

European options are options that can only be exercised on the expiration date [5]. In obtaining the Option value there are several methods that can be used including the Monte Carlo simulation method and the Black-Scholes model. The Black-Scholes method was developed by Fisher Black and Myron Scholes, but the model uses a geometric mean. When stock prices are lognormally distributed, then the geometric mean of stock prices is also lognormally distributed. This results in the geometric average fulfilling one of the assumptions of the Black Scholes model, namely the stock prices used are lognormally distributed. The average stock price using the geometric average can be calculated at maturity, so in this paper we will discuss the execution time of European Options using European Options and will explain the calculation of European Option prices based on the Black Scholes method using geometric averages to determine the value Option contracts and compare the calculated results with European Options

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calculated using the Monte Carlo method. For most types of options, traditional calculation techniques are very difficult to use due to the complexity of the instruments, according to Zhang that the Monte Carlo approach will be more reliable. To produce a very accurate approximation value, pricing stock options using the Monte Carlo method requires many time partitions and data generation. The Monte Carlo method is an alternative that is often used for numerical calculations containing multidimensional integrals in financial computing [6].

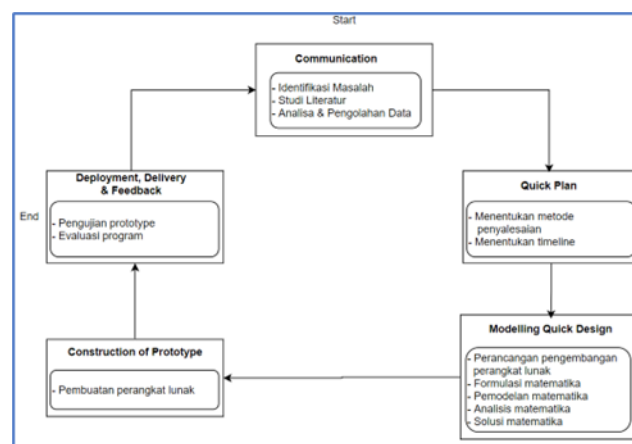
Previous research has been carried out by [3] those discussing option pricing using the black-Scholes model using the finite difference method center time center space (CTCS). The results of this study are by using the European type option pricing formula on Apple shares with the Black-Scholes model using the difference method to CTCS, the call option and put option prices on July 28 2017 are \$5.2558 and \$0.9734 respectively. The call option price on the market is \$5.67(>\$5.2558), so the investor should sell the call option. The put option's market price is \$1.32(>\$0.9734), so the investor should sell the put option. This is because the put option is overpriced (according to BS-CTCS), i.e. the price of the put option on the market is greater than the price of the put option determined by the Black-Scholes model. using different methods to CTCS. Previous research has also been conducted by [7] discussing Asian option pricing using the Monte Carlo simulation method with variance reduction techniques. This study provides the results of calculating Asian call option prices using the Monte Carlo simulation method by applying variance reduction techniques [8]. The simulation gives an Asian call option price of IDR 766.7 with a standard error of 6.2952. Based on the simulations that have been carried out, it can also be concluded that the method of reducing variance with the antithetical variable technique can reduce the standard error of the Monte Carlo method or in other words it can accelerate convergence [9]. This technique provides an average reduction of up to 45.8% increase in efficiency.

Based on the existing description, in this study a study was conducted on the application of the Black-Scholes equation and Monte Carlo on stock option prices and made an application of the application of the Monte Carlo and Black-Scholes equations [10]. The author intends to conduct research by comparing one of the above methods, namely the Monte Carlo Simulation method with the popular method used in determining option prices, namely the Black-Scholes method. The results of the analysis will be compared with the results of previous studies. Comparison of these two methods to find out which of the two methods is better and to get accurate results in determining the price of the European type of Stock Option. SOCA (Stock Option Calculation) is a stock simulation application [11]. This application offers

simulation calculations and data calculations taken from web pages Finance Yahoo. Users can also choose the desired stock options such as buy options or put options. This calculation uses the Monte Carlo and Black-Scholes simulation methods so that the results of the two methods can be compared. The results page also displays the calculation results in graphical form. In addition to performing calculations, users can also view the history of calculations that have been performed [12].

## 2. Methods

In this study the software development method used is a prototype where the prototype method can flexibly adjust to user needs [13]. Literature studies are also conducted to find references in the form of previous research journals that are appropriate to the research topic taken. Figure 1 is the stages carried out in research research. Figure 1 is the flow of the research that will be carried out in this study, in outline the stages can be arranged into the first stage, namely communication, quick plan, modeling quick design, construction of prototype and finally deployment, delivery and feedback [14].

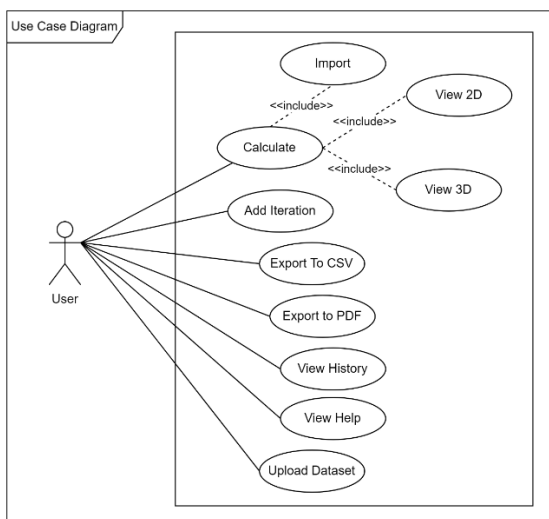


**Fig 1** Research Stages

First, we will examine the Communications process. Initial communication and data collection, namely analysis of user needs. Where to identify problems with research objects, identify old business processes, and present new business processes to overcome these problems. At this communication stage consists of three stages. (a) Study of literature: At this stage the researcher will collect reference materials related to related titles in the form of literature, papers, journals and related theories about Stock Options, European Type Stock Options, Monte Carlo and Black-Scholes. (b) Identification of problems: At this stage the researcher will determine the problem to be solved through the research conducted. The issue covers price analysis of European type stock options. This stage is complemented by finding possible solutions from the basic equations used, as well as implementing them in program form. (c) Data Analysis and Processing: At this stage, the researcher

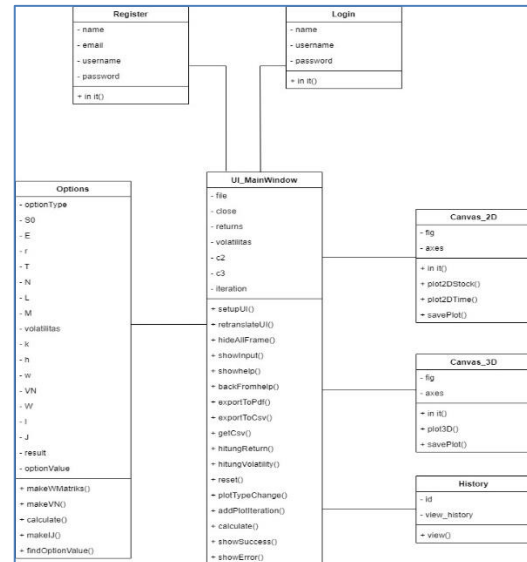
will analyze the data that has been collected by the researcher, to then be processed and used in this study [15]. Next, we will examine the Quickplan process. Making a Quick plan in general determines the direction and concept of the prototype to be developed, this stage helps in optimizing the time and costs required in the prototype development process. The quick plan stage consists of two stages. (a) Determine the settlement method: At this stage will begin to determine the methods that can be used to solve the problems under study or find solutions to existing problems. The methods used to solve the existing problems are the Black-Scholes Model and the Monte Carlo Method in the European type of option. (b) Define timelines: At this stage, the program will be scheduled for each stage in the prototype development method [16].

Next, we will examine the Quick Design Modeling process. This stage is carried out through making designs based on existing features so that the system that is desired by the user is fulfilled. By making a design for the device to be made, it can be used as material in the formation of the application. In this study researchers used UML modelling [17]. The Unified Modeling Language (UML) is a collection of modeling conventions used to define or describe a software system associated with objects. Unified modeling language or better known as UML is used as a tool for designing or modeling systems. [18]. The design used in this study is as follows. First, the use case diagram that will be used in program design is that the actor who uses this program is the user (share player) which can be seen in Figure 2 below:



**Fig 2.** Use Case Diagrams

Next, the class diagram that will be implemented in making program simulations in this study. The class diagram to be used can be seen in Figure 3 [16].



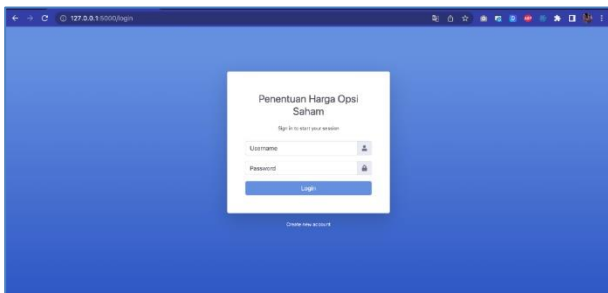
**Fig 3.** Class Diagrams

Next is a study of the Construction of Prototype [19]. Prototype device is made, including improvements. Prototype development is the stage where the prototype that has been planned and specified beforehand, is made in accordance with predetermined concepts and specifications. After making a prototype device, where the prototype is built using a programming language python. Python is an interpretive programming language that is considered easy to learn and focuses on code readability [20]. Then the device will be tested to find out the error on the device that has been made. Next is a study on Deployment, Delivery and Feedback. This stage consists of prototype testing and prototype evaluation and refines the analysis of user needs. This is done so that the application made is in accordance with user needs, so that the purpose of making the application is fulfilled. This stage consists of two stages. (a) Prototype Testing: After designing and developing the software for this website-based system, the next stage is testing which intends to find out whether there are still errors or errors in the prototype. If there are still errors or deficiencies, improvements or additional features can be made to the program. (b) Program Evaluation: This stage is the final stage of this research method, after testing it will be evaluated on the program that has been made whether the program can run properly or there are still errors. In this study, researchers tested using a black box testing. Blackbox testing is software testing which is a functionality test of an application that does not require special knowledge of application program code and user knowledge [16].

### 3. Results and Discussion

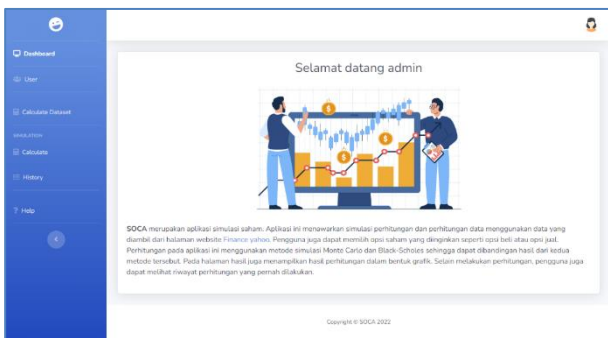
In this session, we will first examine the Implementation process. Registration Page is what will be discussed first. On this page where users can access the website, first log in by entering the username and password. If the user name

and password entered are correct, the system will direct the user to the main page. If the user name and password entered are incorrect, the system will display a warning message. In this session, we will present many figures that can provide an illustration of what we are doing in this research. The login page display can be seen in Figure 4.



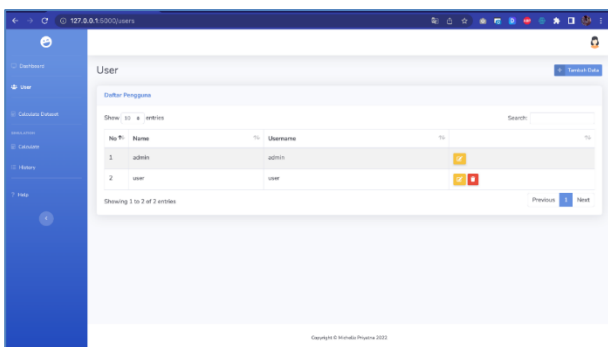
**Fig 4.** Login page

Next, we will examine the Admin Main Page. On the main page the admin can access the Stock Option Pricing application. Admins can do the user menu, calculate dataset, then calculate and history simulations, and there is a help menu, which can be seen in Figure 5.



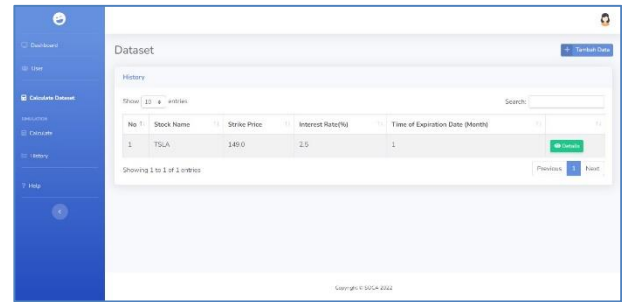
**Fig 5.** Admin Main Page

Next will be studied about the User Menu page. User page you can manage user data such as adding data, changing data, and even deleting user data that is no longer registered with the application, can be seen in Figure 6.



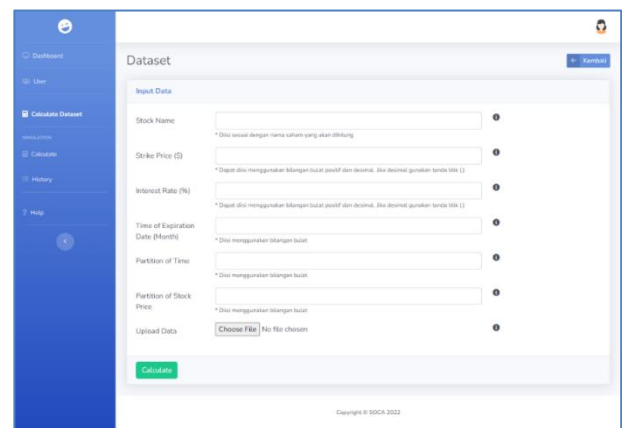
**Fig 6.** User Menu page

The next study is about the Calculate Datasets page. On the calculate dataset page the user can add datasets; besides that he can also see the details of the dataset that has been uploaded, can be seen in Figure 7.



**Fig 7.** Calculate Dataset page

If the user wants to add a dataset, select the add dataset button, then the system will display a data input form, then the user enters data containing the stock name, strike price, interest rate, time of expiration date, partition of time, partition of stock price, and upload data, after that the user selects the calculate button, can be seen in Figure 4.10.



**Fig 8.** Add Dataset Page

The next study is about the Calculate page. On the calculate page the user can add data, select the add data calculate button, then the system will display the input data form, then the user enters data containing the input type, stock price, strike price, interest rate, volatility, time of expiration date, partition of time, partition of stock price, after that the user selects the calculate button. After all data has been entered and is correct, the user can press the calculate button. The display of the calculate results can be seen in Figure 9.



Fig 9. Calculate Results page

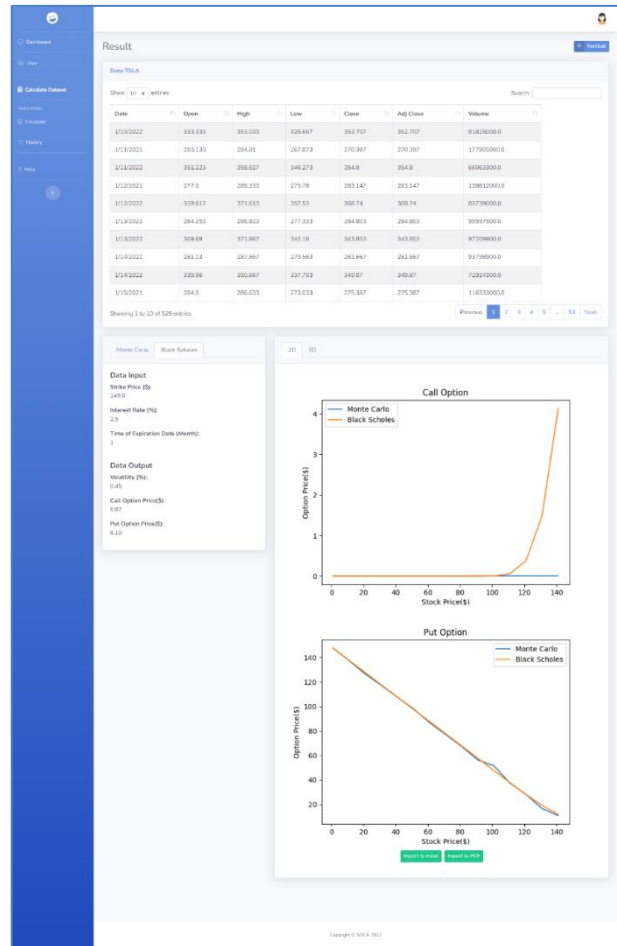


Fig 11. Page Results

Next, we will examine the History page. On this history page, users can usually see information related to stock prices based on date and option type, which can be seen in Figure 10.

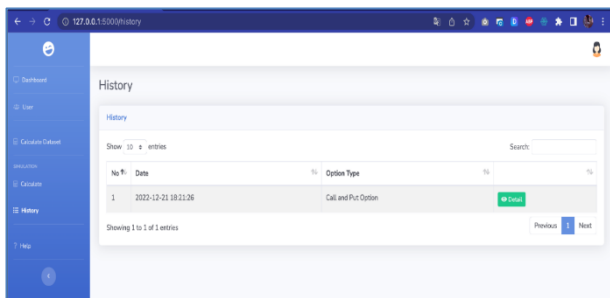


Fig 10. Page History

Next will be studied about the Results page. This results page displays the results of the calculations to determine the price of stock options, which can be seen in Figure 11.

After reviewing the Implementation process, the next process to be studied is the testing process. The first thing that will be discussed is the Evaluation of Stock Pricing on Manualization with the Program. Evaluation of stock pricing in Table 1 and Table 2 is a table that explains the results of the manualization of the Monte Carlo and Black Scholes methods.

It can be concluded that the results of manualization with the program are in accordance with using input data in the form of Tesla data to determine the value of call options and put options. Next, we will examine the Comparative Evaluation of the Black-Scholes Method with Monte Carlo. This comparative evaluation explains the results of the comparison of the Monte Carlo and Black-scholes methods. The following is a comparison of the calculation results of the Monte Carlo and Black-scholes methods, as Table 3 below.

In the 1st month results with a market price of 7.7, based on predictions from Black Scholes and monte carlo, the error value generated from Black Scholes has a higher error value than the monte carlo error value with a ratio of 6:2. It can be concluded that the prediction of call options on TSLA stock prices, monte carlo has better results than black scholes. However, in the predictions for the 3rd and 5th months, it is quite the opposite. Black Scholes value

has better performance than monte carlo. It can be concluded that Monte Carlo has good results if predictions are made in the short term, while Black Scholes will have good performance if predictions are made in the longer term. The next study is about System Evaluation. The system evaluation will be carried out using blackbox

testing. This method is used in blackbox testing focusing on the functionality of the system that has been created. is a test of the Blackbox Testing method. This can be seen in Table 4.

**Table 1** Results of Manualization of the Black-Scholes Method with Monte Carlo

<b>Black-Scholes method</b>	<b>Monte Carlo method</b>
The results of the calculation of the black-scholes method can be concluded that the black-scholes call option calculation produces a call option value = 6.67 and a put option is 8.37 with a period of 1 month	While the results of calculations using the monte carlo method can be concluded that the calculation of the monte carlo call option with simulation 10 is 4.16 and the put option is 3.15. Calculations can be increased by adding simulations based on calculations performed, the value of the call option starts to rise when it is summed up to 50,000 to 100,000. The SE value itself can get smaller depending on the more simulations are done.

**Table 2** Results of the Black-Scholes Method Program with Monte Carl

<b>Black-Scholes method</b>	<b>Monte Carlo method</b>
The results of calculations with the program using the black-Scholes method can be concluded that the calculation of the call option price is 6.87, and the put option is 8.19 within 1 month.	While the results of calculations using the monte carlo method can be concluded that the calculation of the monte carlo call option with simulation 10 is 4.16 and the put option is 3.15. Calculations can be increased by adding simulations based on calculations performed, the value of the call option starts to rise when it is summed up to 50,000 to 100,000. The SE value itself can get smaller depending on the more simulations are done.

**Table 3** Comparative Evaluation of the Black-Scholes and Monte Carlo Methods

<b>The ..... month-</b>	<b>Call Option</b>			<b>Error</b>	
	<b>Black Scholes</b>	<b>Monte Carlo</b>	<b>Market price</b>	<b>Black Scholes</b>	<b>Monte Carlo</b>
1st month	1.42	4.162936114	7.7	6.277296014	3.537063886
3rd month	7.057910205	3.175171791	8.5	1.442089795	5.324828209
5th month	7.347500645	1.662584628	13.3	5.952499355	11.63741537

**Table 4** Black Box Testing Evaluation

<b>Feature</b>	<b>Scenario</b>	<b>Expected results</b>	<b>Test result</b>
Register	The user adds the required user name and password	The account has been successfully registered and can be used to enter the system	Succeed
	The user adds a user name and does not include a password to be registered	A message will appear to fill in the password first	Succeed

Feature	Scenario	Expected results	Test result
Login	The user enters the user name and password to enter the system	The system will display the main page if	Succeed
	The user enters the user name but does not enter the password	The system will display an error message in the system	Succeed
Dashboard user page	Users after logging in will be directed to the main page	The system will display the admin main page	Succeed
User Page	Users can add user data	The system will display the user data form	Succeed
	Users can change user data, by clicking the edit button to make changes to user data	The system will display the user data edit form	Succeed
	Users can delete user data that is no longer active or unregistered	The system will display a message pop-up, if the user wants to delete user data select "OK", otherwise select "Cancel"	Succeed
Datasets Page	Users can add data to datasets, after that select calculate for processing.	The system will display the data form dataset	Succeed
Calculate page	Users can input data after which it will be executed by the system.	The system will calculate the data that has been input right	Succeed
History page	Users can view information on the history page	The system will display a history page that contains information	Succeed
Results Page	Users can see the calculation results by displaying a graph	The system will display the calculation results in the form of a graph	Succeed
PDF export feature	The user presses the export to pdf button on the result page	The system downloads files in the form of files in	Succeed

Feature	Scenario	Expected results	Test result
		pdf format	
csv export feature	The user presses the export to csv button on the results page	The system downloads files in the form of files with csv format	Succeed

Based on Table 4, evaluation using blackbox testing by trying all the features available in the application, it can be concluded that all features or functionality of the system can run properly according to their functions.

#### 4. Conclusion

Based on the results of the research that has been done, there are several conclusions drawn as follows. Stock option prices can be obtained by entering the dataset obtained from yahoo finance, after which the dataset is calculated using the Monte Carlo and Black-Scholes methods. The error value in this study was carried out by simulating the price of a European type call option, where the prediction results from the Monte Carlo and Black-Scholes methods will calculate the difference with the market price. There are differences in the results of pricing European type stock options using the Monte Carlo and Black-Scholes methods. Monte Carlo itself depends on the number of simulations, while Black-Scholes, if seen from the calculations, the results cannot be optimized anymore. However, for Monte Carlo it can still be optimized by adding the number of simulations. Based on the predictions of Black Scholes and Monte Carlo, the error value resulting from Black Scholes has a higher error value than the Monte Carlo error value. This can be obtained because the prediction of the 1st month of call options on stock prices using the Monte Carlo method has better results than Black Scholes. However, in the predictions for the 3rd and 5th months, it is quite the opposite. Black Scholes value has better performance than monte carlo. It can be concluded that Monte Carlo has good results if predictions are made in the short term, while Black Scholes will have good performance if predictions are made in the longer term. Based on the results of stock options calculations using Monte Carlo and Black-Scholes it is known that the performance of the two methods has different accuracy results. The results of Monte Carlo itself depend on the number of simulations, while \Black-Scholes when viewed from the calculations, the results cannot be optimized anymore. However, for Monte Carlo it can still be optimized by adding the number of simulations. Moreover, in developing the Soca-Stock Option Calculation application, the authors obtained various suggestions and input for this application. The following suggestions and input that can be considered: This research uses the

European type of option, for future development it can use other types of options. To make this application even better, several other features can be added as needed.

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#### Author contributions

**Michelle Priyatna:** Conceptualization, Methodology, Software, Field study; **Devi Fitriannah:** Data curation, Writing-Original draft preparation, Software, Validation., Field study; **Samsul Arifin:** Visualization, Investigation, Writing-Reviewing and Editing.

#### Conflicts of interest

The authors declare no conflicts of interest.

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